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Energy production, consumption, policies and recent developments in Turkey

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ABSTRACT

Many factors to be appropriately addressed in moving towards energy sustainability in Turkey are examined. These include harnessing sustainable energy sources, utilizing sustainable energy carriers, increasing efficiency, reducing environmental impact and improving socioeconomic acceptability. The latter factor includes community involvement and social acceptability, economic affordability and equity, lifestyles, land use and aesthetics. On the other hand, Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. Turkey is heavily dependent on expensive imported energy resources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. This article presents a review of the potential and utilization of the energy sources in Turkey.

Contents

1. Introduction

Energy sustainability is becoming a global necessity, given the pervasive use energy resources globally, the impacts on the environment of energy processes and their reach beyond local to regional and global domains, and the increasing globalization of the world's economy. Energy is directly linked to the broader concept of sustainability and affects most of civilization. That is particularly evident since energy resources drive much if not most of the world's economic activity such as industry, transportation, residential, and commercial. Also, energy resources, whether carbon-based or renewable, are obtained from the environment, and wastes from energy processes are typically released to the environment. Finally, the services provided by energy allow for

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good living standards, and often support social stability as well as cultural and social development. Given the intimate ties between energy and the key components of sustainable development, the attainment of energy sustainability is being increasingly recognized as a critical aspect of achieving sustainable development [1].

Energy sustainability is taken here not just to be concerned with sustainable energy sources, but rather to be much more comprehensive [1]. That is, energy sustainability is taken to involve the sustainable use of energy in the overall energy system. This system includes processes and technologies for the harvesting of energy sources, their conversion to useful energy forms, energy transport and storage, and the utilization of energy to provide energy services such as operating communications systems, lighting buildings and warming people in winter. Thus, energy sustainability goes beyond the search for sustainable energy sources, and implies sustainable energy systems, i.e., systems that use sustainable energy resources, and that process, store, transport and utilize those resources sustainably [1–4].

Sustainable development is increasingly becoming a goal to which countries aspire. Overall sustainability has been defined in many ways, and is often considered to have three distinct components: environmental, economic and social [1,2]. These three factors when considered separately usually pull society in different directions (e.g., economic sustainability may be achieved at the expense of environmental and social sustainability). Overall sustainable development in general requires the simultaneous achievement of environmental, economic and social sustainability. Achieving this balance is challenging, and energy factors into each component [1–4].

Energy is used in almost all facets of living and in all countries, and makes possible the existence of ecosystems, human civilizations and life itself. Different regions and societies adapt to their environments and determine their own energy resources and energy uses. The standards of life achieved in countries are often a function of energy-related factors. On the other hand, energy can exist in many forms, and can be converted from one form to another with energy conversion technologies. We use energy carriers, produced from energy sources, in all aspects of living [4].

Some points on energy carriers are worth noting. First, they are closely related to endeavours of people and societies, representing the direct energy forms used to deliver needed or desired energy services. Thus, energy carriers influence living standards and are related to technological development [3]. Also, the difference between energy carriers and sources is important. Energy carriers can exist in a variety of forms and can be converted from one form to another, while energy sources are the original resource from which an energy carrier is produced [4]. Confusion sometimes results between energy sources and carriers because some energy sources are also energy carriers. Hydrogen for example is not an energy source, but rather an energy carrier that can be produced from a wide range of resources using various energy conversion processes. Nevertheless, hydrogen is often erroneously referred to as an energy source, especially in discussions of its potential future role as a chemical energy carrier to replace fossil fuels [3,4].

2. Energy for sustainable development

Sustainable development was defined by the 1987 Brundtland Report of the World Commission on Environment and Development [2] as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition implies that actions of present societies should not threaten cultures or living standards for societies [2]. Other definitions and descriptions have been presented. The degree to which sustainable development can be achieved by countries varies, since countries differ according to such characteristics as size, wealth, living standards, culture, and political and administrative systems. Wealth and advanced technology may make it easier for developed countries to strive for sustainable development, but this is not always the case. The basic motivations and desires of societies, countries, cultures and people to advance appear to be inherent, and these aspirations often require increasing energy use and often yield correspondingly increasing emissions [1–4].

In some ways, the concept of energy sustainability is simply the application of the general definitions of sustainability to energy. In other ways, energy sustainability is more complex and involved [1]. Energy sustainability involves the provision of energy services in a sustainable manner, which in turn necessitates that energy services be provided for all people in ways that, now and in the future, are sufficient to provide basic necessities, affordable, not detrimental to the environment, and acceptable to communities and people. Universal agreement on a definition of energy sustainability has not yet been achieved, but various definitions and descriptions have been presented [2]. Linkages between energy sustainability and factors such as efficiency and economic growth have been investigated [4].

The connection between energy, the environment and sustainable development is worth highlighting [3]. Energy supply and use are related to climate change as well as such environmental concerns as air pollution, ozone depletion, forest destruction, and emissions of radioactive substances [4]. These issues must be addressed if society is to develop while maintaining a healthy and clean environment, especially since the future will be negatively impacted if people and societies continue to degrade the environment. A society seeking sustainable development ideally must utilize only energy resources which cause no environmental impact. However, since all energy resources lead to some environmental impact, improved efficiency and environmental stewardship can help overcome many of the concerns regarding the limitations imposed on sustainable development by environmental emissions and their negative impacts [1].

3. Turkey's energy situation

3.1. Share of the energy sector

Turkey is situated at the meeting point of three continents (Asia, Europe and Africa) and stands as a bridge between Asia and Europe. The country is located in southeastern Europe and southwestern Asia. Its size is 779,452 km^2. Turkey's population was about 73 million in 2007 [10]. Because of social and economic development of the country, the demand for energy is growing rapidly. The main indigenous energy resources are hydro, mainly in the eastern part of the country, and lignite [5]. Turkey has no big oil and gas reserves. Almost all oil and gas is imported, as is high quality coal. Turkey also has a large potential for renewable energies. In Turkey, electricity is produced by thermal power plants (TPPs), consuming coal, lignite, gas, fuel oil and geothermal energy, and hydropower plants (HPPs) [5–8].

Table 1 depicts the historical and projected relationship between population, economic output and energy demand. Several relationships are worth highlighting. First, the population projections signal the slowing down of population growth. At the same time the gross national product (GNP) is expected to nearly double every 10 years. A similar relationship between population, per capita energy demand and total energy demand is projected. The implication of these figures is that energy intensity of the Turkish economy will substantially improve over time, going from 81 Mtoe/GNP/capita in 1973 to 40 Mtoe/GNP/capita in 2000 to 33 Mtoe/GNP/capita in 2020 [10]. The main energy resources of

Table 1
Population, economy and energy.

Years	Population (1000)	GNP/capita	Total GNP	Total energy demand (Mtoe)	Energy/capita (Kep)	Energy intensity
1973	38,072	1994	75,915,568	24.6	646	81
1990	56,098	2674	150,006,052	53.7	957	50
1995	62,171	2861	177,871,231	64.6	1,039	44
2000	67,618	3309	223,342,254	82.6	1,218	40
2010	78,459	5366	421,010,994	153.9	1,962	35
2020	87,759	9261	812,736,099	282.2	3,216	33

Table 2
The amount of fossil energy resources in Turkey.

Sources	Apparent	Probable	Possible	Total
Hard coal (million tons)	428	449	249	1126
Lignite (million tons)	7339	626	110	8075
Asphaltite (million tons)	45	29	8	82
Bituminous schist (million tons)	555	1086	269	1641
Oil (million tons)	36	–	–	36
Natural gas (billion m^3)	8.8	–	–	8

Turkey are hard coal, lignite, asphaltite, petroleum, natural gas, hydroelectric energy, and geothermal energy [9–14].

Turkey's main energy resource is coal, and its share of the country's total energy consumption is about 24% [5]. It is used mainly for power generation, cement production, and steel manufacturing [15,16]. Turkey is one of the biggest producers of lignite in the world. This comes predominantly from deposits of the Afsin-Elbistan Basin, where 7360 million tons lignite is economically usable. The biggest lignite deposits (40% of the total) are in Elbistan [17]. The government plans to increase the total supply from 33.6 million tons of oil equivalent (Mtoe) in 2007 to 118.4 Mtoe in 2020 [4]. It is believed that domestic lignite production will be almost tripled. The amount of fossil energy resources in Turkey is shown in Table 2 [17].

Turkey's energy resources are quite miscellaneous, for example, hard coal, lignite, oil, gas, hydro, geothermal, wood, animal and plant wastes, solar and secondary energy resources, coke and briquettes. These resources are produced and consumed in the country [5]. Turkey does not own large fossil fuel reserves. In the future, it seems that it will be very difficult to meet the anticipated demand for oil, natural gas, and even coal. On the other hand, Turkey has huge reserves of renewable energy sources. Turkey's renewable energy sources are plentiful and extensive. Renewable energy production makes up approximately 14.4% of the total primary energy supply (TPES), i.e. 10.30 Mtoe in 2007, and renewable sources represent the second-largest domestic energy source after coal. Primary renewable energy resources in Turkey are: hydro, biomass, wind, biogas, geothermal and solar. Turkey's renewable energy potential is given in Table 3 [16]. Considering recent studies, the usable hydropower potential of Turkey is estimated at 125,000 GWh/year (34,729 MW), and 38,650 GWh of

Table 3
Turkey's renewable energy potential.

Energy type	Usage purpose	Natural capacity	Technical	Economical
Solar energy	Electric (billion kWh)	977,000	6105	305
	Thermal (Mtoe)	80,000	500	25
Hydropower	Electric (billion kWh)	430	215	124.5
Wind energy (land)	Electric (billion kWh)	400	110	50
Wind energy (off shore)	Electric (billion kWh)	–	180	–
Wave energy	Electric (billion kWh)	150	18	–
Geothermal energy	Electric (109 kWh)	–	–	1.4
	Thermal (Mtoe)	31,500	7500	2.843
Biomass energy	Total (Mtoe)	120	50	32

Table 4
Turkey's annual hydropower potential according to DSI and new criteria.

	Gross Potential (GWh)	Potential according to DSI		Potential according to new criteria	
		Econ. Feasible Potent. (GWh)	Installed Power (M)	Econ. Feasible Potent. (GWh)	Installed Power (M)
Fırat (Euphrates)	84,122	39,375	10,345	46,267	12,176
Dicle (Tıgrıs)	48,706	17,375	5,416	24,353	7,610
Eastern Black Sea	48,476	11,474	3,257	24,239	6,925
Eastern Mediterranean	27,445	5,216	1,490	10,979	3,137
Antalya	23,079	5,355	1,357	9,232	2,638
Coruh	22,601	10,933	3,361	12,431	3,825
Ceyhan	22,163	4,825	1,515	8,865	2,860
Seyhan	20,875	7,853	2,146	9,394	2,609
Kızılırmak	19,552	6,555	2,245	7,821	2,697
Yesilirmak	18,685	5,494	1,350	8,408	2,213
Western Black Sea	17,914	2,257	669	7,166	2,108
Western Mediterranean	13,595	2,628	723	5,438	1,511
Aras	13,114	2,372	631	5,246	1,418
Sakarya	11,335	2,461	1,175	3,967	1,984
Susurluk	10,573	1,662	544	2,643	881
Others (total)	30,744	1,788	546	1,721	507
Total Turkey	432,981	127,623	36,950	188,169	55,099

Table 5
Status of economically viable potential of hydropower in Turkey.

Economically viable potential	Number of hydroelectric power plants	Total installed capacity (MW)	Average annual generation (GWh/year)	Ratio (%)
In operation	172	13,700	48,000	35
Under construction	148	8,600	20,000	14
In program	1,418	22,700	72,000	51
Total potential	1,738	45,000	140,000	100

Table 6
Distribution of under design hydropower plants according to their hydro capacity.

Classification	Number of hydroelectric power plant	Total capacity (MW)	Total annual energy (GWh)	Percentage of total annual energy
<5 MW	139	312	1568	2.17
5 to 10 MW	79	548	2135	2.95
10 to 50 MW	186	4595	18,244	25.22
50 to 100 MW	54	3824	13,524	18.70
100 to 250 MW	36	5527	18,179	25.13
250 to 500 MW	11	3500	11,657	16.11
500 to 1000 MW	3	1791	3199	4.42
>1000 MW	1	1200	3833	5.30
Total	509	21,297	72,339	100

Table 7
Present and planned biomass energy production in Turkey (Ktoe).

Years	Classic biomass	Modern biomass	Total
2005	6494	766	7260
2010	5754	1660	7414
2015	4790	2530	7320
2020	4000	3520	7520
2025	3345	4465	7810
2030	3310	4895	8205
Total	34,658	17,853	52,511

this potential was produced in operating hydropower plants (HPPs) in 2006 [17].

There are 436 sites available for hydroelectric plant construction, distributed on 26 main river zones. Table 4 gives water and hydroelectric energy potential of selected river basins in Turkey. The total gross potential and total energy production capacity of these sites are nearly 50 GWh and 112 TWh/year, respectively, and about 30% of the total gross potential may be economically exploitable. At present, only 35% of the total hydroelectric power potential is in operation (Table 5). The national development plan aims to harvest all of the hydroelectric potential by 2010. The contribution of small hydroelectric plants to total electricity generation is estimated to be 5–10% [18]. Table 6 shows the distribution of under design hydropower plants according to their hydro capacity in Turkey [18].

The Southeastern Anatolia Project (GAP) is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3 million ha of agricultural land. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated are in Turkey. The GAP project on the Euphrates and Tigris Rivers encompasses 22 dams and 19 hydroelectric power plants. Once completed, 27 billion kWh of electricity will be generated and irrigating 1.7 million ha [19–21].

Among the renewable energy sources, biomass is important because its share of total energy consumption is still high in Turkey. Since 1980, the contribution of the biomass resources in the total energy consumption dropped from 20% to 9% in 2006. Biomass in the forms of fuelwood and animal wastes is the main fuel for heating and cooking in many rural areas [22–25]. The total recoverable bioenergy potential is estimated to be about 16.92 Mtoe in 1998 [23]. The estimate is based on the recoverable energy potential from the main agricultural residues, livestock farming wastes, forestry and wood processing residues, and municipal wastes [24]. Table 7 shows the present and planned biomass energy production in Turkey and total biomass production is 7.3 Mtoe in 2005 and will be 52.5 Mtoe in 2030 [26].

Table 8
Turkey's forest potential.

Forest potential	Resources (thousand m^3)	Annual growth (thousand m^3)
High productive (total)	847,032	25,605
Forest	88,300	4813
Other woodlands	758,732	20,792
Low productive (total)	88,479	2459
Forest	34,129	1115
Other woodlands	54,350	1344
Total	935,511	28,064

Turkey's forest potential is shown in the Table 8 [24]. The total forest potential of Turkey is around 935 million m^3 with an annual growth of about 28 million m^3 [23]. The average annual growth rate of the forests is about 3%. Around 90% of this potential includes highly productive forests and other woodlands, the others being low productive forests and other woodlands. Energy forests seem to be the best solution, and it has been estimated that 5 million ha of productive forestland is available to be used as energy forests in Turkey. Turkey is a country with rich agricultural potential, but the amount of utilization is very low. In agricultural residues, the total residues amount calculated in dry base has been measured approximately between 40 and 53 million ton [23,24]. If it is accepted that 80% of cereal can be used and its average humidity rate is 15%, then the total amount of agricultural residues used in power plant would be as the average between 27 and 36 million tons [26].

Turkey is one of the countries with significant potential in geothermal energy and there may exist about 4500 MW of geothermal energy usable for electrical power generation in high enthalpy zones [5]. Heating capacity in the country runs at 350 MW_t equivalent to 50,000 households. These numbers can be heightened some seven fold to 2250 MW_t equal to 350,000 households through a proven and exhaustible potential. Turkey must target 1.3 million households equivalent 7700 MW_t. Geothermal central heating is less costly than natural gas could be feasible for many regions in the country [14]. In addition 31,000 MW of geothermal energy potential is estimated for direct use in thermal applications. The total geothermal energy potential of Turkey is about 2268 MW in 1998, but the share of geothermal energy production, both for electrical and thermal uses is only 1229 MW (Table 9). There are 26 geothermal district heating systems exist now and the contribution of geothermal to TPES is 0.162 Mtoe energy included electricity generation [24–26].

The yearly average solar radiation is 3.6 kWh/m^2-day and the total yearly radiation period is approximately 2640 h, which is sufficient to provide adequate energy for solar thermal applications.

Table 9
Capacities in geothermal utilization in Turkey (2008).

Geothermal utilization	Capacity
District heating	845 MW_t
Balneological utilization	440 MW_t
Total direct use	1235 MW_t
Power production	20.4 MW_e
Carbon dioxide production	120,000 ton/year

Table 10
Solar energy potential for seven regions in Turkey.

	Average radiation (kWh/m^2 year)	Sunshine duration period				
		Maximum (kWh/m^2 year)	Minimum (kWh/m^2 year)	Average (h/year)	Maximum (h/month)	Minimum (h/month)
Southeastern Anatolia	1492	2250	600	3016	408	127
Mediterranean	1453	2112	588	2924	360	102
General Anatolia	1434	2112	504	2712	381	98
Aegean	1407	2028	492	2726	371	96
East Anatolia	1395	2196	588	2694	374	167
Marmara	1144	1992	396	2528	351	88
Black Sea	1086	1704	408	1966	274	84

Table 11
Wind characteristics for some selected cities in Turkey.

Station name	Latitude N (°)	Longitude E (°)	Altitude (m)	Average energy density (W/m^2)	Average wind speed (m/s)	
					At 5 m	At 50 m
Anamur	36.06	32.50	5	52	3.1	4.3
Antakya	36.12	36.10	100	84	4.0	5.8
Ayvalık	39.19	26.42	4	54	3.1	4.2
Balıkesir	39.38	27.53	147	58	2.8	4.2
Bandırma	40.21	27.58	58	301	5.8	6.9
Bergama	39.01	27.11	45	61	3.5	4.9
Bodrum	37.02	27.26	27	85	3.7	5.1
Bozcaada	39.50	26.04	40	317	6.2	8.4
Canakkale	40.08	26.24	2	92	3.9	5.4
Corlu	41.10	27.47	183	103	3.8	5.3
Gökçeada	40.12	25.54	72	79	3.5	5.5
Inebolu	41.59	33.46	64	63	3.7	5.2
Malatya	38.21	38.19	898	51	2.7	3.7
Mardin	37.18	40.44	1080	114	4.3	6.0
Silifke	36.23	33.56	15	50	2.9	3.9
Sinop	42.02	35.10	32	84	3.6	5.1

Table 10 shows solar energy potential in Turkey [23]. In spite of this high potential, solar energy is not now widely used, except for flat-plate solar collectors. They are only used for domestic hot water production, mostly in the sunny coastal regions. In 2007, about 8.0 million m^2 solar collectors were produced and it is predicted that total solar energy production is about 0.390 Mtoe [26,27].

There are a number of cities in Turkey with relatively high wind speeds (Table 11). These have been classified into six wind regions, with a low of about 3.5 m/s and a high of 5 m/s at 10 m altitude, corresponding to a theoretical power production between 1000–3000 kWh/(m^2yr). The most attractive sites are the Marmara Sea region, Mediterranean Coast, Agean Sea Coast, and the Anatolia inland [5]. Turkey's first wind farm was commissioned in 1998, and has a capacity of 1.5 MW [25]. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. The majority of proposed projects are located in the Çeşme, İzmir and Çanakkale regions. In 2007 a record 97 MW of new wind energy capacity was installed, taking the total to 146 MW. As of May 2008, there were about 1300 MW under construction, 1100 MW of new licenses issued and 1500 MW licenses pending. There are also a whopping 78,000 MW of new license applications from the government's latest call. [26,27].

Turkey has significant hydroelectric power resources such as the Southeast Anatolia Hydropower and Irrigation Project, which is also known as the GAP Project [19]. It has more than 104 total plants, installed capacity over 10.2 GW, and it is developing a great deal more, especially as part of the $32-billion project. GAP is such a significant project considered to be one of the biggest water development projects ever undertaken. It includes 21 dams, 19 hydro plants around 7.5 GW of power generating capacity, and a network of tunnels and irrigation canals. The distribution of hydroelectric power potential and the distribution of electrical energy production by resources between 1990 and 2006 is shown in Table 12 [23–26].

3.2. Energy supply, demand and production

By 1980, in contrast, oil supplied about 47% of the primary energy consumed, hard coal and lignite about 18%, electricity 6%, and non-commercial sources such as firewood and animal wastes only 28%. Table 13 shows final energy consumption between 1980–2020 [21]. By 2000, 46.5% of final energy came from petroleum, 19.0% from coal, 13.9% from electricity, 9.7% from gas,

Table 12
Distribution of electrical energy production by resources (GWh).

Resource	1990	1995	2000	2006
Hard coal	621	2232	3819	5467
Lignite	19,500	25,815	34,367	32,654
Natural gas	10,192	16,579	46,217	60,876
Petroleum	3942	5772	9311	11,234
Hydropower	23,148	35,541	30,879	38,655
Wind	N/A	N/A	33	126
Geothermal	80	86	76	176
Other	N/A	222	220	1435
Total	57,543	86,247	124,922	150,623

Table 13
Final energy consumption by source (%).

Energy sources	1980	1990	1995	2000	2010	2020
Coal	18.4	22.7	17.6	19.0	20.5	36.0
Oil	47.1	48.3	50.4	46.5	35.7	27.6
Natural gas	0.1	1.9	6.1	9.7	16.4	10.9
Electricity	6.3	9.5	11.4	13.9	17.7	18.9
Other	28.1	17.6	14.5	10.9	9.7	6.6

Table 14
Sectoral distribution of the general energy demand (Mtoe).

Years	Industry	Household	Transport	Agriculture	Other	Total
1995	18.181	17.475	10.827	2.790	1.514	50.787
1997	22.779	21.374	12.209	3.120	0.158	61.040
1999	26.576	23.021	13.521	3.485	1.604	68.205
2001	30.815	24.708	14.842	3.870	1.651	75.883
2003	35.490	26.414	16.146	4.275	1.700	84.024
2005	40.764	28.238	17.564	4.724	1.750	93.037
2007	46.863	30.125	19.122	5.150	1.800	103.068
2010	57.493	33.193	21.722	5.862	1.890	120.150

Table 15
Total final energy production in Turkey (Mtoe).

Energy sources	1990	2000	2007	2010	2020	2030
Coal and lignite	12.41	13.29	21.68	26.15	32.36	35.13
Oil	3.61	2.73	1.66	1.13	0.49	0.17
Natural gas	0.18	0.53	0.16	0.17	0.14	0.10
Biomass and wastes	7.21	6.56	5.33	4.42	3.93	3.75
Nuclear	–	–	–	–	7.30	14.60
Hydropower	1.99	2.66	4.56	5.34	10.00	10.00
Geothermal	0.43	0.68	0.70	0.98	1.71	3.64
Solar and wind	0.03	0.27	0.22	1.05	2.27	4.28
Total production	25.86	26.71	36.12	39.22	58.20	71.68

and 10.9% from other energy sources, including solid fuels, geothermal, solar power, and wind power [21].

In the mid-1980s, the build, operate, and transfer (BOT) system was launched in an attempt to deal with the energy shortage, under which foreign investors would provide the capital and technology to build plants, operate them for a number of years with guaranteed revenues, and finally transfer the units to the government when the investment had been fully returned [25]. On the other hand, between 1980 and 2007, Turkish electric power demand grew at an average annual rate of 8.4%, among the highest such rates in the world. As of 2007, the government was planning to nearly double the country's generating capacity by 2020 by adding more than 23,000 MW in additional power [5]. Geothermal power could supply up to an estimated 31.5 million kWh of additional capacity, but little progress has been made on exploiting the potential. Sectoral distribution of the general energy demand is shown in Table 14 [23]. Because of social and economical development of the country, the demand for energy and particularly for electricity is growing rapidly. The main indigenous energy sources are hydro, mainly in the eastern part of the country, and lignite. Turkey has no big oil and gas reserves. Almost all oil and natural gas (NG) is imported, as is high quality coal. Turkey also has large potential for renewable energies [25–29].

In 2007, primary energy production and consumption has reached 36 and 140 million tons of oil equivalent (Mtoe), respectively (Table 15 and Table 16) [25,26]. The most significant developments in production are observed in hydropower, geothermal, solar energy and coal production. Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990. However, the total share of renewables in total primary energy supply (TPES) has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system. Turkey has recently announced that it will reopen its nuclear program in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports. As of the end of 2007, installed capacity and generation capacity of power plants reached 45,037 MW and 187,836 GWh, respectively (Table 17).

Gas accounted for 40% of total electricity generation in 2007, coal 28% and oil at about 5%. Hydropower is the main indigenous source for electricity production and represented 25% of total generation in 2005 (Table 17). Hydropower declined significantly relative to 2000 due to lower electricity demand and to take-or-pay contracts in the natural gas market. According to Turkish statistics, the share of hydropower in electricity generation increased to 26% in 2007 [30–36].

Owing to severe economic problems in the last few decades, in addition to fluctuating prices before Turkey's recent severe economic matters, the Turkish natural gas was anticipated to increase excessively rapidly over the next years, with the most important consumers anticipated to be natural gas-fired electric power plants and industrial users. Total natural gas consumption is projected to increase at an annual rate of 9.6% from 15.0 to 169.4 billion m^3 (bcm) over 2000–2025 [25,26]. Power sector gas demand is one of the main drivers for this projected growth and

Table 16
Total final energy consumption in Turkey (Mtoe).

Energy sources	1990	2000	2007	2010	2020	2030
Coal and lignite	16.94	23.32	39.46	39.70	107.57	198.34
Oil	23.61	31.08	42.04	51.18	71.89	102.38
Natural gas	2.86	12.63	43.21	49.58	74.51	126.25
Biomass and wastes	7.21	6.56	5.33	4.42	3.93	3.75
Nuclear	–	–	–	–	7.30	14.60
Hydropower	2.01	2.68	4.56	5.85	8.76	10.0
Geothermal	0.43	0.70	1.90	1.23	1.71	3.64
Solar and wind	0.03	0.27	0.32	1.10	2.27	4.28
Total production	53.05	77.52	140.63	152.23	279.20	463.24

Table 17
Electric power capacity development in Turkey.

Fuel type	2007		2010		2020	
	Installed capacity (MW)	Generation (GWh)	Installed capacity (MW)	Generation (GWh)	Installed capacity (MW)	Generation (GWh)
Coal	16,214	52,616	16,106	104,040	26,906	174,235
Natural gas	12,610	74,200	18,923	125,549	34,256	225,648
Fuel oil	2100	10,120	3246	18,213	8025	49,842
Renewables*	14,112	50,900	25,102	86,120	30,040	104,110
Nuclear	0.0	0.0	0.0	0.0	10,000	70,000
Total	45,037	187,836	65,377	347,922	109,227	623,835

* Renewables include hydropower, biomass, solar and geothermal energy.

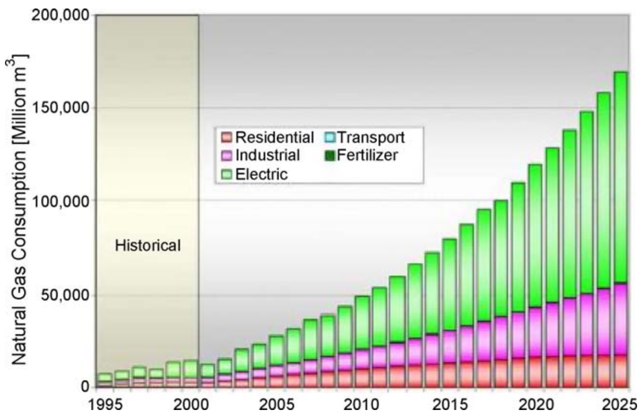


Fig. 1. Natural gas consumption by sector.

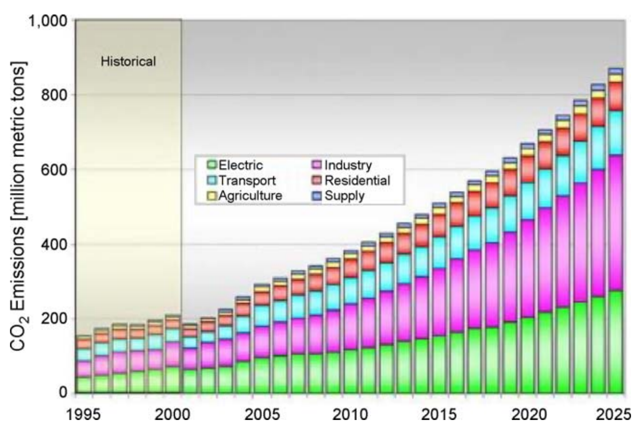


Fig. 2. Historical and forecasted values of CO_2 emissions by sectors.

will account for 112.8 billion m^3 (bcm) in 2025. Industrial demand is the fastest growing market segment with gas expanding from 2.5 to 38.4 bcm during 2000–2025 as shown in Fig. 1.

3.3. Impacts and risks of the observed

Turkey has been undergoing major economic changes in the 1990s, market by rapid overall economic growth and structural changes. However, the share of the informal sector in the Turkish economy remains high. Turkey's population has reached 72 million and remains one of the fastest growing from 1990 to 2004 in the OECD. Major migrations from rural areas to urban, industrial and tourist areas continue. In this context, Turkey confronts the challenge of ensuring that economic growth is associated with environmental and social progress, namely that its development is sustainable [37–40].

Turkey ratified the Framework Convention on Climate Change in February 2004 and is developing its climate change strategy [24]. After that, on May 24, 2004 Turkey became the 189th party by signing Framework Convention on Climate Changes [28,36]. After this stage is completed Turkey will have to fulfill new liabilities such as to present national GHG inventories and national declaration reports to Convention Secretariat regularly, and will also actively participate in efforts carried on global wide so that convention will achieve its ultimate goal [24]. In 2003, it is estimated that 36% of CO_2 emissions occurred due to energy, 34% due to industry, 15% due to transportation and 14% due to other sectors such as housing, agriculture and forestry and in 2020 40% will occur due to energy, 35% due to industry, 14% due to transportation and 11% due to other sectors [25]. Fig. 2 shows the historical and forecasted values of CO_2 emissions by sectors [28].

Turkey's demand for energy and electricity is increasing rapidly. Energy consumption has increased at an annual average rate of 4.3% since 1990 [24]. As would be expected, the rapid expansion of energy production and consumption has brought with it a wide range of environmental issues at the local, regional and global levels [28]. Turkey's carbon dioxide (CO_2) emissions have grown along with its energy consumption. Emissions in 2000 reached 211 million metric tons [26]. Table 18 shows direct GHG emissions in Turkey by sectors between 1990 and 2010 [41]. Total CO_2 emissions increase at an average rate of 5.8%/year and reach 871 million ton/year by 2025 [28]. The industrial contribution changes the most noticeably, rising from 31% to 42% driven by the high growth in industrial final energy as well as the continued reliance on solid and liquid fuels in this sector [37–40].

Air pollution is becoming a great environmental concern in Turkey. Air pollution from energy utilization in the country is due to the combustion of coal, lignite, petroleum, natural gas, wood and agricultural and animal wastes. On the other hand, owing mainly to the rapid growth of primary energy consumption and the increasing use of domestic lignite, SO_2 emissions, in particular, have increased rapidly in recent years in Turkey. The major source of SO_2 emissions is the power sector, contributing more than 50% of

Table 18
Direct greenhouse gas emissions in Turkey.

Greenhouse gases (GHGs)	1990	1995	2000	2005	2010
Total direct GHG (Gg)*	200.720	241.717	333.320	427.739	567.00
CO_2 (%)	88.67	87.42	90.93	92.90	94.53
CH_4 (%)	10.77	10.05	7.68	5.97	4.52
N_2O (%)	0.56	2.53	1.40	1.14	0.95
Emission fractions generated from fuel consumption					
Direct GHG (Gg)*	146.735	172.933	258.314	352.733	491.995
CO_2 (%)	97.3	97.8	98.2	98.6	98.9
CH_4 (%)	2.1	1.6	1.4	1.0	0.7
N_2O (%)	0.6	0.5	0.4	0.4	0.4
Emissions fractions generated from industrial processes					
Direct GHG (Gg)*	35.424	47.251	52.930	52.930	52.930
CO_2 (%)	99.5	89.1	93.5	93.5	93.5
CH_4 (%)	0.1	0.1	0.1	0.1	0.1
N_2O (%)	0.4	10.8	6.4	6.4	6.4
Emissions fractions generated from the burning of agricultural residues					
Total direct GHG (Gg)*	591.05	550.25	578.5	578.5	578.5
CH_4 (%)	76.92	76.96	76.96	76.96	76.96
N_2O (%)	23.03	23.04	23.04	23.04	23.04

* Direct greenhouse gases, CH_4 and N_2O emission values were given as CO_2 equivalents.

Table 19
Estimated CO_2 and CH_4 emissions in different energy consuming sectors in Turkey.

Energy consuming sectors	CO_2 emissions (Gg)				CH_4 emissions (Gg)			
	1990	1995	2000	2005	1990	1995	2000	2005
Energy and cycle	50,965	61,664	87,986	98,665	0.70	0.88	1.33	1.65
Industry	37,123	41,246	55,563	66,432	3.56	3.84	5.52	5.98
Transportation	25,878	32,460	44,688	56,789	3.61	4.82	5.88	6.46
Households	21,356	23,456	26,976	29,776	134.25	118.67	119.76	125.65
Others	6,143	8,456	10,980	12,657	11.32	10.12	9.78	9.54
Total	141,465	167,282	226,193	264,319	153.44	138.33	142.27	149.28

Gg: Giga gram.

Table 20
Total emission estimates in Turkey (Mg/year).

Years	PM	SOx	NOx	VOC	CO	CH_4
1980	4,113,234	1,735,344	342,876	335,567	321,897	128,473
1985	4,465,323	2,123,134	446,786	384,678	895,654	147,942
1990	4,976,456	2,620,105	612,345	427,864	1,443,276	153,441
1995	6,012,112	3,123,344	696,678	413,976	1,584,554	138,334
2000	6,964,226	3,486,623	834,776	443,568	1,786,645	142,873
2005	7,789,677	4,134,543	956,744	465,765	1,986,865	149,673
2010	8,986,687	4,875,789	1,214,762	504,443	2,243,543	154,534
2015	9,345,256	5,668,922	1,764,322	539,543	2,554,567	159,789
2020	10,122,342	6,234,544	2,344,176	591,344	2,943,876	162,356

the total emissions. As given in the literature [28], SO_2 concentrations in the flue gas of some lignite fired power stations are extremely high and differ notably between power plants, owing to the variation of the sulfur content of the fuels. Although the NO_2 emissions are lower than the SO_2 emissions in Turkey, they have likewise increased rapidly, following the growth of energy requirements. Contrary to the development of SO_2 emissions, a similar upward trend of NO_2 emissions has been observed in many European Community countries [5,28] as well, resulting mainly from increased traffic density. Also, in Turkey, nearly 50% of the total NO_2 emissions are from the transportation sector, while less than 20% are caused by power generation [41].

The main pollutants associated with energy use are sulfur oxides (SOx), nitrogen oxides (NOx) and total suspended particulates (TSP). In Turkey, these emissions come mostly from the combustion of coal, oil products and fuelwood. The latter is especially responsible for indoor air pollution. SO_2 and TSP levels have decreased in some big cities such as Ankara and Istanbul [10]. However, overall emissions have grown significantly and many millions of people, especially in smaller cities where gas distribution networks do not yet exist, remain exposed to pollutant levels. This causes health problems, including respiratory diseases, and, hence, increased hospitalization costs, restricted activity days and shortened life expectation. Per capita emissions in 2005 were 32 kg, below the OECD average of 38 kg [41,42]. Table 19 shows the calculated CO_2 and CH_4 emissions for the main sectors, such as energy, industry, transportation, households and others in Turkey. Table 20 also shows total emission estimates with five year intervals in the country.

Owing to considerable variation observed in the runoff in terms of seasons, years and regions, it is absolutely necessary on the major rivers in Turkey to have water storage in order to ensure the use of the water when it is necessary. Consequently, for these reasons, priority has always been given to the construction of water storage facilities, and significant progress has been registered in the construction of dams throughout the 50 years that have elapsed since the establishment of the State Hydraulic Works (DSI). Table 21 shows water resources in Turkey. On the other hand, with the projects developed primarily by the DSI and other institutions engaged in water resource development, actual water consumption in Turkey as of 2006 reached about 40 km^3, which corresponds to only 36.3% of the economically exploitable water potential, of which 29.4 km^3 (75%) has been for irrigation, 5.9 km^3 (16%) for domestic uses and 4.7 km^3 (9%) for industrial uses [41–46].

The Southeastern Anatolia Project (GAP) is one of the largest power generating, irrigation and development projects of its kind in the world, covering three million ha of agricultural land. This is over 10% of the cultivable land in Turkey [35]. The land to be irrigated is more than half of the presently irrigated area in Turkey. GAP is an integrated development project. It is expected to affect the entire structure of the region in its economic, social and cultural dimensions through a process of transformations to be triggered by agricultural modernization. The GAP project on the Euphrates and Tigris Rivers encompasses 22 dams, and once completed, 1.7 million ha will be irrigated [18,19].

Water consumption was 54 billion m^3 in 2006 (20% of total freshwater resources), 38 billion m^3 of which was supplied from surface waters and the remainder from groundwater. Seventy- six percent of that volume was used for irrigation, followed by drinking water (14%) and industrial uses (10%). However, access to piped water can be a problem for a particular segment of the population [35]. Nearly 100% of urban dwellers but only 85% of rural residents have access to safe drinking water. Moreover, water supply is also a problem for new residents in peripheral and/or

Table 21
Water resources in Turkey.

Water resources	
Mean annual precipitation	642.6 mm
Volume of the mean annual precipitation	501 km^3
Surface water	
Annual flow	186.05 km^3
Annual run-off-coefficient	0.37
Present annual consumption	27.5 km^3
Groundwater	
Annual safe yield	12.2 km^3
Allocated amount	7.6 km^3
Present annual consumption	6.0 km^3

1 km^3 = 1 billion m^3.

Table 22
Unit energy cost.

Technology group	€ cents/kWh (electricity)	
	Unit cost	Unit cost
	1995	2020
Fossil fuel/centralized electricity	4–6	–
Fossil fuel/decentralized electricity	8–12	–
Large hydro	3–13	2.6–11.2
Small hydro	4–14	3.6–10.1
Wave/tidal	6.7–17.2	6.1–11
Residues	4–10	2.5–6
Energy crops	10–20	4.5–13
Wind generators	5–10	2.5–7.3
Solar thermal	20–24	8–10
Solar PV	31–29	8–22
Wastes	4–5	4–6
Geothermal	5–8	5–7

illegally settled areas of Turkey's cities [14,26]. Water demand is expected to increase due to agricultural uses. The DSI estimates that the amount of water needed in 2010 will be 55 billion m^3, of which 78% will be for irrigation, 13% for urban and 9% for industry [35]. For example, 4.5 million ha of agricultural land are currently irrigated, which is 16% of all agricultural land and 17% of all potentially irrigable land [47]. It is possible to irrigate about 26 million ha of agricultural land although only 8.5 million ha of which will be economically viable. Since new investments are being made for irrigation, drinking water, industry and energy, incentives should be adopted to discourage irrigation in non-economical land [18,19,48].

3.4. Energy financing

In 2006, 30 billion US$ were invested in the Turkish economy, 26% of which were in the energy sector. Turkish electricity distribution company (TEDAS) had a 51% share in the electricity investment program, 56% of its investment was in generation, 34% in transmission lines and 10% in other equipment [9]. Meeting national demand in accordance with Turkey's economic targets requires allocate sufficient financing for investments in the energy sector. Long-term planning studies indicate a heavy burden of investments between 2006 and 2020 amounting to some 72 billion US$. Turkey's funding needs for the energy sector is the highest of the southern and eastern Mediterranean countries. The needs of each energy sector are [9,22,24]:

- Electricity: 58 billion US$ (82%),
- Gas: 7 billion US$ (9%),
- Oil: 5 billion US$ (6%),
- Solid fuels: 2 billion US$ (1%).

Table 23
Net power generating cost by energy input.

Fuel input	Cost (US cents per kWh)
Hard coal	4.37
Lignite	2.99
Fuel oil	3.14
Diesel	16.24
Geothermal	2.46
Natural gas	3.86
Average thermal (EUAS)	3.56
Dam	0.14
Lake	1.11
Run-of-river	0.68
Average hydro (DSI)	0.16
Average EUAS + DSI	1.96

Table 24
Setup costs for the energy sources.

Type of energy source	Setup cost (US$)
Hydropower plant (may differ according to the body of the dam)	750–1200
Thermoelectric power plant relying on lignite	1600
Thermoelectric power plant relying on the imported coal	1450
Thermoelectric power plant relying on natural gas	680
Nuclear power plant	3500
Wind power plant	1450
Thermoelectric power plant relying on the petroleum	2000
Power plant relying on solar energy	Not complete yet

The total investment required for power plants and distribution lines up to 2010 is expected to be around 45 billion US$, 19 billion of which will be under the BOT and BOO models [9]. The huge size of this investment makes it impossible to lay the burden entirely on public finances. Private capital has to be introduced into Turkey's electricity sector to meet these requirements. Table 22 shows the unit energy costs of the technological groups in the years 1995 and 2020 and Table 23 shows net power generating costs of the year 2005 [9,12].

Of the total hydropower potential of 430 TWh/year, 123 TWh/year, the economically feasible potential, is currently used. Plans for the rational use of Turkey's hydropower are already completed, and 55 hydropower plants with a total capacity of 7.1 GWh, comprising 20% of the total hydro power capacity, will soon be tendered under the BOT model. On the other hand, 11 GWh of capacity, using lignite, gas and hard coal is planned to be constructed by 2010. Investment needs in the coal sector for the period 2005–2020 will be around 1.6 billion US$. Investment requirements in the oil sector are expected to be around 4.3 billion US$, 65% for oil pipeline projects and 30% for refining over the same period [22]. The average setup cost for energy sources is given in Table 24 [9,12].

4. Rational energy use and renewables

4.1. Energy consumption and renewable energy policies

The electricity losses come from the transmission and distribution systems. The loss in the transmission line of Turkey is about 2.5–3%, which is within world standards. However, the distribution loss is considerably high at 15%. It is expected that the distribution losses will be reduced. Cogeneration, or autoproduction, is known as Combined Heat and Power (CHP), which has been developed by governmental support to support the continuing need for additional electricity generation. There were only for cogeneration plants in operation in 1994, with a total capacity of only 30 MW_e. Since then, incentives were offered by TEDAS in the form of a 100% tax deduction, duty exemptions for autoproduction facilities, and guaranteed purchasing of any surplus electricity [15]. By mid-2006, this has been improved in Turkey so much that, there were 120 operating cogeneration plants with a total capacity of 2960 MW_e, and 173 cogeneration plants representing another 12,300 MW_e, under evaluation by the MENR [26]. The total installed cogeneration capacity was expected to reach up to 7000 MW_e by 2007. That means it will represent about 20% of Turkey's total installed electricity generating capacity [26].

However, the government needs to audit major energy users to discover which could cut back consumption. In addition, a shift in relative energy prices to reflect long-run costs might induce industrial restructuring that would take Turkey's energy endowment into account. Moreover, energy policy makers need to improve management of firewood and agricultural wastes, which continue to play an important role in the rural energy economy. In

1995 National Energy Conservation Centre (NECC), with the participation of the European Union, completed a modeling system to have better forecast consumption in the industry residential building and transport sectors in order to determine energy savings measures better. According to results, the NECC estimated that 13.2 Mtoe could be saved annually in Turkey [5,25,26].

Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. Total renewable energy supply declined from 1990 to 2007, due to a decrease in biomass supply. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources [11,25].

Turkey spent a total of US$ 125 million (2007 prices and exchange rates) on government energy RD&D between 1980 and 2007. In this period, 15.6% of its total energy research and development (R&D) budget (US$ 18.4 million) was allocated to renewable energy. Government R&D expenditures for renewables followed the general trend in overall energy R&D expenditures, rising in the late 1980s and falling in the early 1990s. Public funding increased substantially in 1997 [25]. Among the renewable technologies, geothermal received the most sustained funding over the past two decades and the highest level of funding, equivalent to US$6.1 million or 37% of the renewables R&D expenditures between 1980 and 2007. Market deployment policies for renewables started in 1984 with third-party financing, excise and sales tax exemptions. Capital grants were offered in 2001. The Turkish government's approach to the deployment of renewables reflects its priorities to develop indigenous and renewable resources in conjunction with the expansion of privately owned and operated power generation from renewable sources [11,20,25].

The build-own-transfer (BOT) and the build-own-operate (BOO) schemes were put it place in 1984 and financed major power projects (not limited to renewables) with the main objective of attracting private investors [25]. BOT projects were granted a treasury guarantee. Although BOT and BOO approaches attracted significant investment, they also created large contingent public obligations with the government covering the market risk through take-or-pay contracts [25]. The economic crisis of 2000 and pressure from the International Monetary Fund, however, brought an end to the treasury guarantees, except for the 29 BOT projects whose contracts were already in place [5,25,26].

The real beginning for renewable energy policy was the definition of renewable energy sources in the decree of the Modification of the License Regulation in the Electricity Market in 2003 [12]. Before then, there was no national renewable energy policy and few government incentives existed to promote market deployment of renewable energy. However, the Electricity Market Licensing Regulation, in itself, is not expected to be sufficient to overcome the high invesment cost, risk and lack of security associated with the entrance of renewable power plants into the electricity market [11,20,25,26].

Turkey is to be recipient of a US$202 million renewable energy loan provided by the World Bank to be disbursed as loans via financial intermediaries to interested investors in building renewable energy sourced electricity generation [5,25]. These loans are expected to finance 30-40% of associated capital costs. The aim of the Renewable Energy Program is to increase privately owned and operated power generation from renewables sources within a market-based framework, which is being implemented in accordance with the Electricity Market Law and the Electricity Sector Reform Strategy [12]. This program will assist the Directorate of the Ministry of Energy and Natural Resources (MENR) in the preparation of the renewable energy law, as well as to define the required changes and modifications related to legislation such as the Electricity Market Law to better accommodate greater private sector involvement [26,46].

4.2. Energy efficiency evolution

The industrial sector accounted for 42% of total final energy consumption and for 54% of electricity consumption in 2007, while the agriculture, household and services sectors together accounted for 40% of final energy consumption and 46% of electricity consumption [12]. Although all four sectors have important potential for energy conservation, industry has been targeted as a priority area for energy conservation programs owing to the projected rapid expansion of industrial energy demand. On the other hand, the structure of industry in Turkey is energy intensive.

In Turkey, the per capita energy consumption (measured as TPES/population) in 2006 was equal to 1.62 t of oil equivalent (toe), much less than the average of 5.10 toe for all IEA countries [25], but its growth is much faster than the IEA average and is projected to remain fast in the coming two decades as the economy develops. Energy intensity (measured as toe/$1000 GDP at 1990 prices and exchange rates) in 2006 was 0.34 toe, compared with an IEA average of 0.26 toe, and has increased slowly in recent years. If purchasing power parities are used, Turkey's energy intensity fell well below the IEA average [25].

According to estimates of the MENR, Turkey has an energy conservation potential equal to 10–12 Mtoe/year, or nearly 13–15% of total consumption in 2006, and therefore, $3.8 billion could be saved through conservation measures in three main end-use sectors [26]. Within the industrial sector, iron and steel manufacturing and cement production are by far the largest energy users [36]. However, the petrochemical industry, the fertilizer industry, the textile industry, ceramic products and paper manufacturing, as well as sugar production, are also major users. According to the MENR, potential for conservation in these sectors ranges from 25% to 35% in the country [26].

On the other hand, in 2006, a study of the MENR assessed the potential for energy conservation in industry at 4.6 Mtoe and an approximate cash value of $1.4 billion/year. The total investment required to achieve this conservation potential would be close to $2.8 billion. The payback period for these investments would range from a minimum of one year to a maximum of three years. The measures required to bring these savings about would include the adoption of various forms of waste heat recovery, increased use of cogeneration of electricity and heat/steam and the use of more efficient boilers [26].

In the residential/commercial sector, more than 70% of the energy consumed is used for heating. Energy use per unit of building area could be reduced by nearly half through the application to all buildings of the new Heat Insulation Standards on building envelopes, issued in 2000 [25]. While existing buildings require 200–250 kWh/m^2, the new standards could bring requirements down to 100–150 kWh/m^2. At current rates of building stock turnover, the estimated energy efficiency gains could take several decades to materialize. In addition, major efficiency improvements are also possible in power generation by increasing power plant size from the existing average of 150–340 MW by requiring higher efficiency specifications for new plants and by increasing the use of cogeneration, especially in industry.

Turkey has dynamic economic development and rapid population growth. It also has macro-economic, and especially monetary, instability [5]. The net effect of these factors is that Turkey's energy

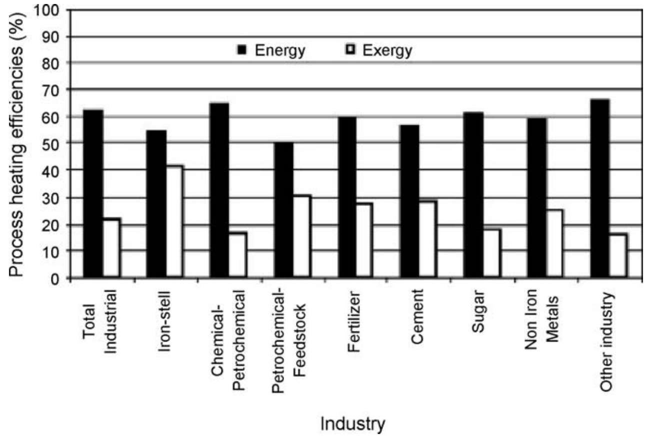


Fig. 3. Mean heating energy and exergy efficiencies of the industrial sector.

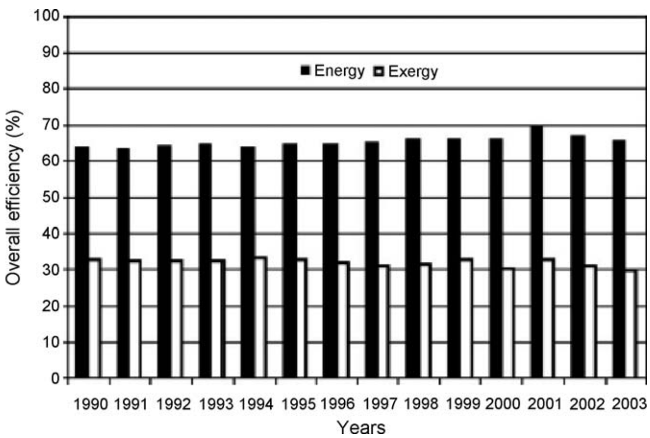


Fig. 4. Overall energy and exergy efficiencies of the Turkish industrial sector.

demand has grown rapidly almost every year and is expected to continue growing. The domestic share of total energy consumption is 37%, and between the years 2000 and 2010, the cost for needed energy will be approximately 55 billion US$. The government has been planning for 81% of this amount as an investment. Considering the country's economic conditions, Turkey must come up the plan which reduces the share of fossil fuels, increases energy production (including use of more alternative energy sources), and changes the coarse of long-term energy plans into very effective and applicable solutions [26].

According to the studies conducted by Turkish State Statistics Institute (DIE) in 2002 and 2005, on the basis of the results obtained from about 1350 of these manufacturers, their total energy consumption of the places of employment, which annually consume 500 toe or above, constitute 75% of the industrial energy consumption of Turkey [10]. In case of industrial sector, the iron and steel sectors consumes 35% of the total energy consumption. In this sector, when the cost of the energy is investigated, this share breaks down into 48% in the iron and steel sector, 32.5% in the ceramics industry and 55% in the cement industry. On the basis of the cost of the energy, the share of the metal and soil industry, out of the total value of Turkey ranges from 11% to 55% [49–52]. The graphical representation of the mean heating energy and exergy efficiencies for the year 2003 is shown in Fig. 3. Overall energy and exergy efficiencies of the Turkish industrial sector are shown in Fig. 4 [38].

The values of energy and exergy productions for 2002 according to renewable energy sources are illustrated in Table 25 [38]. As can be seen in this table, total energy and exergy inputs to the renewable sector were 428.62 and 395.68 PJ in 2002, respectively. In 2002, of the six renewable energy sources, wood had the largest share with 47.58%, followed by hydropower with 22.15%, geothermal with 14.82%, and biomass with 13.00%, and other renewables with 3.45%. In 2002, of Turkey's total end-use energy, 42% was used by the industrial sector, followed by the residential–commercial sector at 31%, the transportation sector at 19%, the agricultural sector at 5% and the non-energy use at 3% [23].

The Turkish residential–commercial sector includes space heating, water heating, cooking and electrical appliances for energy consumption [51]. In 2007, of Turkey's end-use energy, 29.6% was used by the residential sector, while the share of this sector in this breakdown is expected to continue to decrease at approximately 8–10% per year and to reach 20% in 2020. The highest contributions came from renewable resources (including wood) with 36.24%, fuel with 39.45% and electric with 24.31% in 2007, respectively [26]. In 2007, the highest contributions came from wood with 190.80 PJ, while the share of this resource in this breakdown is expected to continue to decrease at approximately 3–5% per year and to reach 128.54 PJ in 2020. This is due to the economic development in Turkey. However, natural gas utilization has continuously increased in the Turkish residential–commercial sector for space heating, water heating and cooking purposes in several cities [48–50].

Table 25
Energy and exergy production values for Turkey's renewables and total in 2002.

Renewable energy sources (RESs)	Energy (Exergy)	Renewables production (PJ)	Share of RESs in Turkey's total production (%)	Share of RESs in Turkey's total production (%)	Share of RESs in Turkey's total consumption
Biomass	Energy (Exergy)	55.67 (58.45)	13.00 (14.77)	4.76 (5.05)	1.74 (1.86)
Wood	Energy (Exergy)	203.94 (214.13)	47.58 (54.12)	17.43 (18.48)	6.37 (6.82)
Hydropower	Energy (Exergy)	94.94 (94.94)	22.15 (23.99)	8.12 (8.19)	2.96 (3.02)
Geothermal	Energy (Exergy)	63.52 (18.34)	14.82 (4.64)	5.43 (1.58)	1.98 (0.58)
Solar	Energy (Exergy)	10.32 (9.60)	2.41 (2.42)	0.88 (0.83)	0.32 (0.31)
Wind	Energy (Exergy)	0.23 (0.23)	0.05 (0.06)	0.24 (0.02)	0.96 (0.01)
Total	Energy (Exergy)	428.62 (395.68)	100.00 (100.00)	36.64 (34.14)	13.38 (12.61)

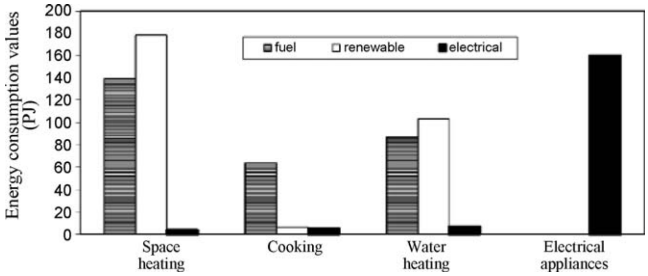


Fig. 5. Distribution of the energy consumption values in the Turkish residential–commercial sector.

Natural gas constituted 190.70 PJ of the energy used in this sector in 2007 and is projected to account for 453.68 PJ of that in 2020. In addition, utilization of renewable energy is spread in the Turkish residential–commercial sector, especially from sunlight for water heating, from geothermal for water heating and space heating and from biowaste for general usage. Fig. 5 illustrates the use of energy and exergy as well as the shares of the resources in this sector for the year of 2002. The share of the energy consumption in the residential–commercial modes is as follows: space heating with 43%, water heating with 26%, cooking with 10% and electrical appliances with 21% in the year studied [51].

Refrigeration requires the largest fraction of electricity with 38% in 2002, followed by lighting with 35%. A variation of the overall mean energy and exergy efficiency values for subusers in the Turkish residential–commercial sector is shown in Fig. 6. As can be seen in Fig. 6, where a comparison of energy and exergy utilization efficiency values for the Turkish residential–commercial sector is also illustrated, the energy efficiencies in 2002 range from 50.14% to 65.87%, while the exergy efficiencies vary from 4.2% to 18.7%. This sector shows considerable important and comparable losses of energy and exergy. In terms of exergy loses, this sector ranks rather differently, accounting for about 81–95% of all exergy loses. Fig. 6 indicates the need of saving in the use of energy and to improve habits of energy use in this sector and its subsectors. Space heating constitutes the longest energy loss, followed by water heating and cooking activities in the Turkish residential–commercial sector [38].

From the evaluation of Fig. 6, it may be concluded that the Turkish residential–commercial sector has about equal and fairly high energy efficiencies, while it indicates a very poor performance in terms of its exergy efficiency values. This study indicated that exergy utilization in Turkey was even worse than energy utilization. In other words, Turkey represents a large potential

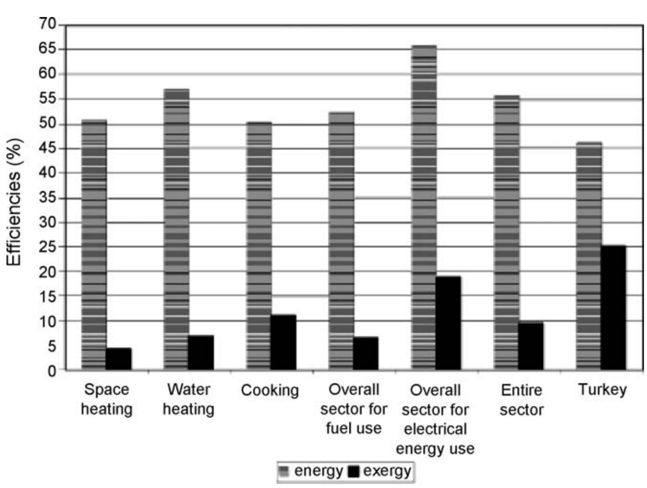


Fig. 6. Energy and exergy utilization efficiencies in the Turkish residential–commercial sector.

for increasing the exergy efficiency. It is clear that a conscious and planned effort is needed to improve exergy utilization in Turkey [38].

Heat insulation has a big energy saving potential, but in Turkey this saving is so less than how much it should be. According to the calculations for 500,000 buildings, it was found that the saving could be 1,720,000,000$ in 2007, considering that the buildings which have taken licence since 2000 have been built according to the regulations [48]. The energy efficiency of Turkish industrial sector and energy and exergy efficiencies of Turkish residential–commercial sectors are mentioned above, but it is difficult to find studies about the energy efficiency of Turkish tertiary sector [25–27].

4.3. Renewable energy evolution

The total renewable energy production and consumption of Turkey are equal to each other, varying between 9.6 and 10.8 million tons of oil equivalent (Mtoe) each for the 1990–2006 period [23,26,28]. Their share in total energy production varies on average between 37% and 43%, while in total consumption, it varies between 15% and 22% for the same period. The production of biomass that includes wood and dung is the highest in 1992, reaching 7.2 Mtoe. The second highest is hydroelectric production, which reached 3.5 Mtoe in 1998 [5,26,28]. The production of geothermal and solar energy is negligible compared with biomass and hydroelectric power, varying from 0.122 to 0.388 Mtoe. On the other hand, Turkey's first wind farm was commissioned in 1998 and has a capacity of 1.5 MW. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities, of which 57 MW is at an advanced stage in negotiations [52–60].

The main barriers for development renewable energy are: lack of financial resources and proper lending facilities, particularly for small-scale projects constitute, lack of detailed renewable energy resource assessments and data banks pertains to Turkey like to many other countries. But, lack of awareness and knowledge is not a big barrier in Turkey. Renewable energy is recognized as a major potential for indigenous, clean energy production. Awareness rising is still a key to involvement, particularly of community based and non-governmental organizations [55–60].

The process of liberalization, restructuring and privatization in the energy sector is vital. It should be prevented any delays in the introduction of competition. It should be created a favorable environment for investment. The most important handicap for foreign investors is Turkish bureaucracy [51]. The permission for a foreign investor can be taken through one-year period with applying numerous different associations. New government had promised to make the permission producer easier [12].

No subsidy policies exist within this frame. Introduction of both subsidies and ways to overcome commercialization barriers as well as the realization of good practices are of utmost importance [51]. Technology developed and/or transferred needs standardization and then replication. There is a need to evaluate applied renewable energy technologies in detail as a precondition for technology transfer. Environmental protection measures need to be considered in technology development. High initial capital costs, high operation and management costs must be brought down to attract private investors and facilitate technology transfer. Local production of renewable energy technology can reduce the investment costs significantly [51].

4.4. Benefits of rational energy use and renewables

Hydroelectric generation, biomass combustion, solar energy for agricultural grain drying and water heating, and geothermal

energy have been in use in the country for many years [50–52]. Domestic water heating is the primary active solar technology. In Turkey, about 35,000 solar water heating systems have been installed since the 1980s. This is a minute fraction of the total potential. About 50% of existing dwellings could be fitted effectively with a solar water heater. If this potential were extended to 2025, the deployment of approximately 5 million systems would be required. This could save an estimated 30 PJ (9.0 TWh) per year of oil, coal and gas and 2.0 TWh per year of electricity, giving a saving of 5.0 million tons of CO_2 per year, or just under 1% of current Turkey CO_2 production. Detailed energy and economic comparisons of air-to-air heat pumps and conventional heating systems for the Turkish climate have been reported [61]. This study demonstrated that the heat pump offers distinct economic advantages over the oil and coal-fired boiler systems, but is not an economic alternative to the gas-fired heating system [62].

Because the unit price of the gas is almost four times less than that for electricity in Turkey, to become competitive with a gas-fired boiler, either the capital cost of the heat pump must be substantially reduced. As the average energy equivalent of agricultural residues is 17.5 MJ/kg [57–59], then the annual energy equivalent of agricultural residues is varies from 470 to 620 PJ. So, agricultural residues have a high potential to take the place of the lignite and hard coal used in electricity production. Biogas systems are considered to be strong alternatives to the traditional space heating systems (stoves) in rural Turkey. Geothermal heat pumps are a relatively new application of geothermal energy that has grown rapidly in recent years. They use the earth as a heat sink in the summer and a heat source in the winter and, therefore, rely on the relative warmth of the earth for their heating and cooling production [48–52]. On the other hand, the biggest benefit of geothermal heat pumps is that they use 25–50% less electricity than conventional heating or cooling systems. Geothermal heat pumps can also reduce energy consumption, and corresponding air pollution emissions, up to 44% compared to air source heat pumps and up to 72% compared to electric resistance heating with standard air conditioning equipment [49].

Solar energy and heat pump systems are two promising means of reducing the consumption of fossil fuel resources and, hopefully, the cost of delivered energy for residential heating [61]. An intelligent extension of each is to try to combine the two in order to further reduce the cost of delivered energy. Solar heat pump systems can be classified, according to the source of heat that supplies the evaporator of the heat pump, as either parallel, series or dual. In parallel systems, the heat pump receives energy from the outdoor air, and the collected solar energy is supplied directly for either space heating or for heating water. In the series system, solar energy is supplied to the evaporator of the heat pump, thereby raising its temperature and increasing the coefficient of performance. In the dual source configuration, the evaporator is designed so that it can receive energy from either the outdoor air or from the solar energy store. Studies show that there is a great potential for using a solar heat pump combination for domestic heating/cooling applications in Turkey [61–63].

Turkey, currently, does not have an organized photovoltaic (PV) program. Global energy strategies and policies are laid down in periodic five-year development plans [27]. Government has no intention in PV production. PV cells are produced in various research establishments in order to study the feasibility of local manufacturing. So far none of these studies yielded a positive result in order to justify a mass production facility in Turkey. There are more than 30,000 small residential areas where solar powered electricity would likely be more economical than grid supply. Another potential for PV market is holiday villages at the long coastal areas. These facilities are frequently far from the main grid nodes and require additional power when solar isolation is high. Unfortunately energy demand in Turkey is so large that utilities are concentrating on large conventional power plants and peak load facilities. The last five-year development plan, being prepared, foresees a more ambitious program and estimates approximately 40 MW_p installed power by the year 2010 [25–27].

5. Proposals for sustainable energy development

Turkey cannot perform a clear strategy concerning the renewable energy sources because of energy costs and investment costs. The State encouraged the private sector for natural gas combined circuit plants and guaranteed to buy the generated electricity with a low cost and with special conditions. The state wants to wipe out this shortage with nuclear energy on a large scale and with geothermal energy on a small-scale in heating. Concerning the last year, state did not give any projection and targets like it has given for natural gas combined circuit plants to the investors which will build up solar energy and wind energy power plants, because energy costs of these kind of plants are so expensive [51].

Turkey is interested in renewable energy resources and gives effort to provide the sustainability of using these energy resources [64–66]. The state encouraged the municipalities in respect of the geothermal energy and gave them the permission to behave self-governing. After that the municipalities started to use geothermal basins one after another for heating of buildings. These show that the development in geothermal energy is available with all aspects. The state obligates the institutions which consumed higher amount of energy than a specific capacity, to keep energy manager and consultant for the waste energy in the energy plants. The State tried to stabilize the amounts of produced and consumed energy with this way [64–76].

In Turkey, the efficiency of energy utilization is not as high as Europe yet. The state leads the private sector to the World Bank's credit in all sources of renewable energy [5]. The State says that it will be the guarantor for the 30–40% of the cost of the private sector's investments which are for their own needs. If the private sector can find buyer, it can sell the electricity produced in these plants. There is an interconnect system in electric distribution in Turkey. For example, the electrical power which is generated in Aegean region, is given to the primary network if no buyer is founded and afterwards this power is distributed to a region where power is needed. But the private sector has to appropriate this power for a precisely low cost to have the opportunity to sell it to the interconnect system of the State. In Turkey power generation from renewable energy resources can have never been appropriated for low costs. It may be beneficial if the producers will use these powers for their own needs. But geothermal energy is very promising for the future [25–27].

The insulation materials and consciousness of insulation are on a developed situation. There is no a clear strategy like Mediterranean strategy in Turkey. There is a development of energy utilization and energy efficiency in Turkey [50,75]. The awareness of industrial institutions is on a good level and it is developing in the public level too. The Turkish people are in a better situation in these subjects than it is supposed by Europeans. Turkey has to develop the usage of solar and wind energies because solar energy and wind energy potentials are good [24]. The usage of ground sourced and water sourced heat pumps in greenhouse and building heating has to be developed. The usage of geothermal energy has to grow up rapidly. Energy recovery materials and technology have to be developed to perform the policy of energy recovery definitely. The question mark of European Union about the Russian natural gas is current for Turkey too. It is not clear that this subject will be ballasted [25,27,76].

The actual situation of the petrol apart from the cost may change so seriously. After 2020, petrol may be used only for production of chemical materials, which have to be produced from petrol [51]. The most long-term petrol is Iraq petrol, but the situation of that region is not clear. The new petrol regions have long life too however they are not of high quality. For a sustainable development of renewable energy resources and settling to the Mediterranean strategy, ground sourced and water sourced heat pump systems, wind and solar energy power plants have to be kept unobstructed always [49]. It can be useful that the energy potentialities such as coal gasification and waste gasification will be kept unobstructed. Coal is a polluting energy source but after gasification, there is a possibility for mixing the coal gas with natural gas and giving the mixture to the system after the mixture is cleaned. In addition to that, there is the opportunity of emission control in coal gasification systems [72].

The new and renewable energy technologies will not be in a highly developed situation yet when the usage of petrol is going to be impossible. In this situation, countries can lean to the coal if they have coal potentiality. Measures have to be taken for using coal with a clean method when this tendency is occurred [72]. Biogas, animal and plant wastes are not so unimportant for energy production, even if they are considered to be insufficient. Biogas can be obtained from leaves and tree wastes. The renewable energy technologies and the energy quantities which are necessary for production per unit have to be kept always in the journal and policy of the country. Legal regulations have to be performed and the State has to give effort to make the public assimilate these regulations highly [58,59].

6. Conclusions

Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. It is expected that the demand for electric energy in Turkey will be 300 billion kWh by the year 2010 and 580 billion kWh by the year 2020. Turkey is heavily dependent on expensive imported energy resources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewables. On the whole, Turkey has substantial reserves of renewable energy sources, including approximately 1% of the total world hydropower potential. There is also significant potential for wind power development. Turkey's geothermal potential ranks seventh worldwide, but only a small portion is considered to be economically feasible.

References

[1] Rosen MA. Energy sustainability: a pragmatic approach and illustrations. Sustainability 2009;1:55–80.
[2] World Commission on Environment and Development. Our Common Future; Oxford University Press: Oxford, UK, 1987.
[3] Lior N. Energy resources and use: the present situation and possible paths to the future. Energy 2008;33:842–57.
[4] World Energy Assessment Overview: 2004 Update; Johansson, T.B., Goldemberg, J., Eds.; United Nations Development Program: New York, USA, 2004.
[5] MEF, Ministry of Environment and Forestry. First national communication of Turkey on climate change, (Eds. Apak, G., Ubay, B), MEF, Ankara, Turkey, 2007.
[6] Kaygusuz K. Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey. Renew Sustain Energy Reviews 2009;13:242–59.
[7] Akpınar A, Kömürcü MI, Kankal M, Ozelçer H, Kaygusuz K. Energy situation and renewables in Turkey and environmental effects of energy use. Renewable and Sustainable Energy Reviews 2008;12:2013–39.
[8] Ozturk HK, Yilanci A, Atalay O. Past, present and future status of electricity in Turkey and the share of energy sources. Renewable and Sustainable Energy Reviews 2007;11:183–209.
[9] TEDAS, Turkish Electricity Distribution Company. Electricity generation statistics in 2007 for Turkey. Available from http://www.tedas.gov.tr (accessed date 10.11.2008)
[10] DIE, State Institute of Statistics. Basic Statistic Indications of Turkey in 2006, available From: http://www.die.gov.tr/(accessed date 12.10.2007).
[11] IEA, International Energy Agency. Renewables information 2006, IEA, Paris, 2007.
[12] TEIAS, Directorate-General of Turkish Electricity Transmission. Electricity statistics in Turkey for 2007, available from http://www.teias.gov.tr (accessed date 04.08.2008).
[13] Arsel, M, Kaygusuz, K. Energy Politics and Policy in Turkey, in "Environmentalism in Turkey" (Eds. Adaman, F., Arsel, M), Ashgate Publishing Company, Burlington, USA.
[14] TÜBITAK, Vizyon (2003). 2023 Teknoloji Öngörüsü Projesi, Enerji Ve Dogal Kaynaklar Paneli, 24 Temmuz, Rapor Ekleri, EK-A, Türkiye, Dünya Ve OECD Verileri
[15] Kilic FC, Kaya D. Energy production, consumption, policies, and recent developments in Turkey. Renewable and Sustainable Energy Reviews 2007;11: 1312–20.
[16] Kaya D. Renewable energy policies in Turkey. Renewable Sustainable Energy Reviews 2006;10:152–63.
[17] Akdeniz F, Caglar A, Güllü D. Recent energy investigation on fossil and alternative nonfossil resources in Turkey. Energy Conversion and Management 2002;43:575–89.
[18] DSI, State Water Works. Turkey hydropower report, Ankara, Turkey, 2007.
[19] GAP, Southeastern Anatolian Project. Hydropower in the GAP region, www.gap.gov.tr.
[20] IEA, International Energy Agency. Energy policies of IEA countries: Turkey 2001 review. Paris: OECD/IEA; 2001.
[21] Salvarlı H. Some aspects on hydraulic energy and environment in Turkey. Energy Policy 2006;34:3398–401.
[22] Demirbaş A. Energy balance, energy sources, energy policy, future developments and energy investments in Turkey. Energy Conversion and Management 2002;42:1239–58.
[23] WECTNC, World Energy Council-Turkish National Committee. Turkey Energy Report in 2006. Ankara, Turkey, 2007.
[24] Bilgen S, Keles S, Kaygusuz A, Sarı A, Kaygusuz K. Global warming and renewable energy sources for sustainable development: a case study in Turkey. Renewable and Sustainable Energy Reviews 2008;12:372–96.
[25] IEA, International Energy Agency. Energy policies of IEA countries: Turkey. Paris: IEA; 2005.
[26] MENR, Ministry of Energy and Natural Resources. Energy report of Turkey in 2007. Turkey, Ankara; available from http://www.enerji.gov.tr [accessed 10.06.08].
[27] EIE, General Directorate of Electrical Power Resources Administration. Renewable energy potential in Turkey, available from http://www.eie.gov.tr [accessed 02.04.07].
[28] Turkey Energy and Environmental Review, Task 7: Energy Sector Modeling, Prepared by Conzelman G, Koritarov V, Center for Energy, Environmental, and Economic Systems Analysis (CEEESA), Argonne National Laboratory, 2002.
[29] Kilic AM. Turkey's natural gas necessity, consumption and future perspectives. Energy Policy 2006;34:1928–34.
[30] Hepbasli A. Development and restructuring of Turkey's electricity sector: a review. Renewable and Sustainable Energy Reviews 2005;9:311–43.
[31] Tunc M, Camdali U, Liman T, Deger A. Electrical energy consumption and production of Turkey versus world. Energy Policy 2006;34:3284–92.
[32] Balat H. A renewable perspective for sustainable energy development in Turkey: The case of small hydropower plants. Renew Sustain Energy Reviews 2007;11:324–46.
[33] Yüksel I. Hydropower in Turkey for a clean and sustainable energy future. Renewable and Sustainable Energy reviews 2008;12:1622–40.
[34] Balat M, Balat H, Acici N. Thermal- electricity power plants (TPPs) in Turkey. Energy Exploration Exploitation 2004;22:367–76.
[35] Ocak M, Ocak Z, Bilgen S, Keles S, Kaygusuz K. Energy utilization, environmental pollution and renewable energy sources in Turkey. Energy Conversion and Management 2004;45:845–64.
[36] SPO, State Planning Organization. Nineth Five-Year Development Plan. Energy Report of Turkey, DPT, Ankara, Turkey, 2006.
[37] Hepbasli A, Ozalp N. Development of energy efficiency and management implementation in the Turkish industrial sector. Energy Conversion and Management 2003;44:231–49.
[38] Utlu Z, Hepbasli A. Estimating the energy and exergy utilization efficiencies for the residential–commercial sector: an application. Energy Policy 2006;34: 1097–105.

[39] SIS, State Institute of Statistics. Energy Consumption in Residences in 1998. Prime Ministry of Turkey, Ankara, 2002.
[40] TEIAS, Turkish Electricity Transmission Company. Electrical energy development in Turkey and some statistical figures, available from: http://www.teias.gov.tr/.
[41] Akcasoy K, Onder F, Guven S. Statistical Evaluation of Greenhouse Gas Emissions of Turkey Between the Years of 1970 and 2010. Turkey: Ankara: DIE; 2000.
[42] SIS, State Institute of Statistics. Statistic Yearbook of Turkey in 2006. Prime Ministry, Republic of Turkey, Ankara, 2008.
[43] Yüksek O, Kaygusuz K. Sustainable development of small hydropower plants (SHPs). Energy Sources 2006;28:1105–18.
[44] TEAS. Turkish Electricity Company. Electricity generation-transmission statistics of Turkey: 2004.Ankara; 2005.
[45] DSI, State Water Works. Hydropower potential in Turkey. Turkey: Ankara; 2004.
[46] Greenhouse Gas Mitigation in Energy Sector for Turkey, Working Group Report, MENR Ankara, Turkey, 2005. www.iklim.cevreorman.gov.tr (accessed on 06.08.07).
[47] Turker MF, Ayaz H, Kaygusuz K. Forest biomass as a source of renewable energy in Turkey. Energy Sources 1999;21:705–14.
[48] DSI, State Water Works. Turkey water report, Ankara, Turkey, 2009.
[49] Hepbasli A, Canakcı C. Geothermal district heating applications in Turkey: a case study of Izmir–Balcova. Energy Conversion and Management 2003; 44:1285–301.
[50] Hepbasli A. Energy conservation studies on residential heating systems: an application for Izmir, Turkey. International Journal of Global Energy Issues 2001;15:247–63.
[51] Koyun A. Energy Efficiency and Renewable Energy in Turkey. In: Mediterranean and national Strategies for Sustainable Development. Marseilles, France: Plan Bleu; 2007.
[52] Kaygusuz K, Kaygusuz A. Geothermal energy in Turkey: the sustainable future. Renewable and Sustainable Energy Reviews 2004;8:545–63.
[53] MENR/TEAS. Base Case Analysis of Energy Development and CO_2 Emissions in Turkey. Ministry of Energy and Natural Resources (MENR), Ankara, Turkey, November 2000.
[54] Ministry of Environment (ME). Turkish National Environmental Action Plan (NEAP), ME, Ankara, Turkey, 2007.
[55] Kaygusuz K, Sarı A. Renewable energy potential and utilization in Turkey. Energy Conversion and Management 2003;44:459–78.
[56] Yüksek O, Kömürcü MI, Yüksel I, Kaygusuz K. The role of hydropower meeting the electric energy demand in Turkey. Energy Policy 2006;34:3093–103.
[57] Kaygusuz K, Turker MF. Biomass energy potential in Turkey. Renew Energy 2002;26:661–78.
[58] Acaroglu M, Aksoy AS, Ogut H. The potential of biomass and animal waste of Turkey and the possibilities of these as fuel in thermal generating stations. Energy Sources 1999;21:339–45.
[59] Balat M. Use of biomass sources for energy in Turkey and a view to biomass potential. Biomass Bioenergy 2005;29:32–41.
[60] Hepbaslı A, Ozgener L. Development of geothermal energy utilization in Turkey: a review. Renewable and Sustainable Energy Reviews 2004;8:433–60.
[61] Kaygusuz K. Performance of solar-assisted heat pump systems. Applied Energy 1995;51:93–109.
[62] Kaygusuz K. Experimental and theoretical investigation of latent-heat storage for water- based solar heating system. Energy Conversion Management 1995;36:315–23.
[63] Kaygusuz K, Gültekin N, Ayhan T. Solar-assisted heat pump and energy-storage for domestic heating in Turkey. Energy Conversion and Management 1993;34:335–46.
[64] Oztekin S, Bascetincelik A, Soysal Y. Crop drying program in Turkey. Renew Energy 1999;16:789–94.
[65] Kaygusuz K. Renewable and sustainable energy use in Turkey: a review. Renewable and Sustainable Energy Reviews 2002;6:339–66.
[66] EIE, Electrical Power Resources Survey and Development Administration. Potential of Turkish Wind and Solar Power, www.eie.gov.tr (accessed on 20.05.07).
[67] Ogulata RT. Energy sector and wind energy potential in Turkey. Renewable and Sustainable Energy Reviews 2003;7:469–84.
[68] International Energy Agency Heat Pump Centre. Heat Pumps: An opportunity for reducing the greenhouse effect (brochure), The Netherlands, 1997.
[69] TUSIAD, Turkish Industrialist' and Businessmen's Association. Turkey's energy strategy on the brink of the 21st century: An overview, This report prepared by Ultanir, M.Ö, İstanbul, Turkey, 1998.
[70] EIE, Electrical Power Resources Survey and Development Administration. Hydroelectric Power Plant Projects Carried out by EIE, Ankara, Turkey, pp. 1-45, 2005.
[71] Ileri A, Gurer T. Energy and exergy utilization and Turkey during 1995. Energy 1998;23:1099–106.
[72] Ercan Y. Emission-reduction strategies for energy supply systems near urban areas. Energy 1999;24:419–31.
[73] Kaygusuz K, Kaygusuz A. Renewable energy and sustainable development in Turkey. Renewable Energy 2002;25:431–53.
[74] Kaygusuz K. Sustainable development of hydropower and biomass energy in Turkey. Energy Conversion and Management 2002;43:1099–120.
[75] EIE, Electrical Power Resources Survey and Development Administration. Solar Energy Activities of EIE. Available from: http://www.eie.gov.tr.
[76] İZODER, Isı Su Ses ve Yangın Yalıtımcıları Derneği. Türkiye'de Yalıtım Gerçeği, 2006.